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# Vehicle Level Human Performance Modeling for Military Vehicle Simulation

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## ABSTRACT

The U.S. Army Research, Development, and Engineering Command Tank Automotive Research, Development, and Engineering Center (RDECOM TARDEC) is currently developing a Vehicle Level Human Performance Model (VLHPM) as an advance design tool that can operate alone or in coordination with human research participants. This model has been used to reduce the number of participants necessary for testing vehicle capabilities, effective survivability measures, and joint operability and its functionality is being expanded for use in upcoming experiments. The VLHPM has benefited RDECOM by providing a portable alternative to human participant use, reducing development of prototypes, manpower costs and the need for training. This paper discusses the structure and capabilities of the model, architectural challenges of developing and integrating the model, and factors involved in testing and verifying the model.

## INTRODUCTION

TARDEC's approach to the development of new military vehicles, such as those in the Future Combat Systems (FCS) program, and the use of new technology to improve upon existing systems, uses Modeling and Simulation (M&S) to reduce the equipment, manpower, and time requirements of development, testing, and life-cycle support. The M&S approach provides a framework for problem solving applicable to a number of similar projects, including the a persistent, secure distributed simulation environment suitable for problem solving related to FCS, and joint experiments testing the teamwork capabilities of FCS. TARDEC has used this M&S approach to obtain valuable results in collaborative experiments with other Army agencies, the Naval Air Command, and Armed Forces Canada.

One component of TARDEC's M&S toolbox is the Vehicle Level Human Performance Model (VLHPM). This paper will focus on the VLHPM's role in providing M&S solutions and the factors involved in its development and use.

## BACKGROUND

The Vehicle Level Human Performance Model (VLHPM) was developed as a stand-in for a human participant in an experiment involving the operation of an FCS vehicle. It is for use in parallel with TARDEC's other M&S systems, especially the Crew integration and Automation Testbed, or CAT. The CAT contains a Human-Machine Interface (HMI) representative of HMI that is expected to be in every FCS vehicle. The design and functionality of the CAT crewstation will now be described as a basis for understanding the requirements for and intended functionality of the VLHPM.

TARDEC traditionally uses soldiers as subjects for validation of this HMI. This testing methodology requires a number of participants equal to the number of people that would man the vehicles in a real tactical exercise like the one used for the experiment's scenario. Ideally, these participants should be Soldiers who receive a full week of training on the CAT crewstation.

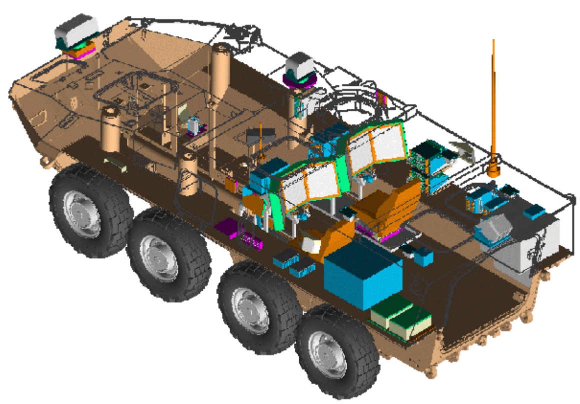

**Figure 1. CAT Vehicle and Crew Station placement**

The CAT hosts an embedded simulation system (ESS) which allows virtual operation of the crewstation as well as simulated training, mission planning and mission rehearsal. The ESS relays information between the simulated environment and the CAT crewstation. The CAT Advanced Technology Demonstration will extend

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the basic crewstation design to include the fight, scout and carrier military operational specialties. The CAT HMI also supports the command and control of unmanned systems through both semi-autonomous and teleoperation modes as well as simulated direct and indirect fire. If adopted for FCS, the crewstation design used for the CAT will benefit the Army by reducing repair training and maintenance costs, reducing operational training time and increasing number of common components through use of the common crewstation for all FCS vehicle types. It will also reduce vehicle crew size, allowing for force multiplication, and increase soldier survivability by moving the crew deeper into the vehicle's hull.

Evaluations for experimentation require each soldier use a CAT crewstation to interact with the simulation. The CAT prototype hardware is expensive and soldier availability in wartime is limited. A complementary system for evaluations requiring more than one manned vehicle can allow for experiments on a larger scale, by reducing the need for equipment and human resources.

The goal of the VLHPM system is to replicate any behavior required of a human experiment participant inside a CAT crewstation. VLHPM controlled simulated vehicles can be used alongside manned CAT HMI controlled simulated vehicles in the same experiment. While it cannot currently perform any possible task that could be undertaken by a human, it is able to simulate a range of typical behaviors and can substitute for a human operator in a wingman vehicle that would otherwise be played by a participant in a CAT. A VLHPM controlled vehicle is simulated using three desktop computers, making the system much easier to transport than a crewstation. It requires no human interaction to run during simulation. Starting and stopping the VLHPM can be done by the researchers running the experiment with a few mouse clicks, following simple written instructions. These factors make the use of a VLHPM system preferable when the set of required behaviors is within the capabilities of the current system.

## ARCHITECTURE

Army Research Laboratory's (ARL) IMPRINT (IMproved Performance Research INtegration Tool) application was chosen as the basis for the VLHPM project. It is an analysis tool for building behavioral models, including algorithms and performance data that allow IMPRINT to predict how a human operator would perform in the scenario being modeled. The VLHPM originally used IMPRINT 6 and was subsequently upgraded to run within IMPRINT 7. IMPRINT's ability to interface with other software is limited, despite improvements in version 7, because of length limits on variable names and the use of a COM interface as the only means of interaction with software outside of the model itself. These limitations render it incapable of communicating directly with the Embedded Simulation System. Therefore, the VLHPM development team designed a C++ adapter that can interpret incoming data and format outgoing data appropriately. The adapter program also synchronizes simulation time between itself and the IMPRINT model, displays of information about the simulated vehicle's current state, and performs complex calculations not related to actual human cognition of the problem.

The adapter makes use of a configuration file to tailor the model's behavior to the experiment scenario. This configuration file currently contains a scan angle, a position relative to the lead vehicle for driving in formation, and the fire permissions assigned to the VLHPM. This information is fed to the IMPRINT model at start-up. Fire permissions can be changed while the experiment is running, through the adapter GUI.

The current functionality includes most of the basic tasks that would be performed by an FCS ground vehicle. It can drive in formation, following a lead vehicle. It can scan for other vehicles and discriminate between friendly, hostile, and ambiguous targets, then send a spot report and engage a target, call for fire, or take no action as appropriate to the situation. It can also use any survivability measures that are being simulated on the vehicles. Planned updates to the VLHPM will add new behaviors, including the ability to fire upon a specified target upon request.

Vehicle position and scan angle are specified in a configuration file loaded through the adapter. This allows the operator to change formation between experiment runs or between different VLHPM vehicles in the same experiment run. Upcoming additions will also allow the vehicle to change formations during the experiment run, for example to switch from wedge formation to a line when following the lead vehicle over a bridge. Vehicle type configuration is currently hand set to a definite value before the experiment, but the VLHPM can be quickly modified to reflect the configuration of multiple FCS vehicles and use that vehicle's available weapons and resources appropriately.

## TECHNICAL CHALLENGES

Implementing the VLHPM presents a number of technical concerns different from those faced in CAT implementation or the use of other human-controlled inputs.

In the early stages of experiment planning, precise information about the scenarios and expected vehicle behavior must be gathered. The expected behaviors must be determined well in advance to insure that no tasks are beyond the capabilities of the VLHPM. The most difficult tasks for the VLHPM involve behaviors that come naturally to a human driver and the ability to perform these behaviors is often assumed by scenario authors. Changes to the scenarios must be communicated to the VLHPM development team and reviewed in case any additional VLHPM development is required as a result of the changes.

As noted above, human behavior cannot always be easily implemented. Soldiers manning a CAT are already trained in appropriate tactics, but the VLHPM design team must research these behaviors so that they are correctly implemented. Subject matter experts are consulted before adding these behaviors to the model, to verify that the developers' interpretation is correct. The VLHPM cannot communicate with CAT drivers via radio; an alternate method of sharing information might be required if communication by radio is an assumption of the scenario. The VLHPM cannot interpret visual images; location and identification of objects found in a visual scan is simulated in a manner that does not entirely reflect human perception. The design team attempts to work around these shortcomings in way that is as close to modeling true human behavior as possible.

Messages sent to the ESS can be formatted by the adapter so that they are treated no differently from messages originating at a CAT crewstation. Interpreting messages from the ESS can be more complicated. As noted, IMPRINT places limits on the length of variable names, so it cannot send some of the longer variable names as they are used in the ESS. The adapter translates between IMPRINT's internal names and the conventional names used in the ESS. At times it is also less cumbersome to transmit reduced data to the model; for example, instead of a site/host/ID array to identify each hostile entity, the adapter identifies hostiles to the IMPRINT model using a single number. The emphasis within the model is on code that clearly expresses the behavior and workload of the human represented within the model. Anything that would detract from this clarity without enhancing the model's fidelity to human behavior or that represents calculations a human would estimate through sensory input and/or intuition, rather than the mathematical calculations required by the computer, is placed in the adapter.

This shortcoming has not severely impacted VLHPM development, but it increases the threat of producing a VLHPM that does not accurately reflect human performance. The development team carefully examines all planned modifications to insure that all actual human behavior is modeled in IMPRINT, where the existing data on performance measures helps to insure that the model is realistic, and only delegate support functions and calculations to the adapter.

## MAINTENANCE AND TESTING

Maintenance of the VLHPM relies upon coordination with the ESS development team to insure continued compatibility between the ESS and VLHPM. The current VLHPM, using IMPRINT 7, was completed in December 2006.

It is the development team's intent to continuously maintain a model with basic functionality that will work with the current ESS, even if it does not always include the most recent features or compatibility with the most recent release of IMPRINT. This will allow experiment participation to continue even if development has not yet caught up. However, while there may be multiple development branches, it is intended that all functionality will be merged into one core model that can be configured as necessary to fit the needs of any experiment. This is entirely feasible through the use and expansion of the configuration file, and reduces the amount of work to be done in making all models compatible with the current ESS.

Testing and validation is done in several steps. The human performance data provided within IMPRINT is assumed to be valid. Of greater concern are the fidelity of the model to real human decision-making and the logical integrity of the model and adapter. The behavioral model is compared to any documents or military personnel descriptions available and a common sense test of the behavior described in the model is carried out by looking at it step by step. The adapter is similarly subjected to visual inspection of code. The debugging tools within IMPRINT, including the "Animation" option displaying the progress through the model as it's executed, are used as a preliminary check of logic and syntax of the model. The adapter is similarly debugged using the embedded tools within Microsoft Visual Studio. The complete VLHPM is then run in concert with the ESS and a CAT crewstation as leader in test scenarios. Any deviation of the VLHPM's behavior from that which is expected triggers another review of the code.

The adapter contains an optional text display on screen, as a method of tracking down errors related to the exchange of data between it and IMPRINT. This allows real-time inspection of the data exchange while the simulation is running. It can also be printed to a text file simultaneously.

The upcoming Distributed Command Experiment will be used as an opportunity to gather information about the VLHPM's ability to perform as requested in the experiment requirements. It will be tested with regard to tightness of formation, scan accuracy, and targeting accuracy.

## CONCLUSION

The VLHPM provides a portable alternative to human participant use, intended to reduce manpower costs, training, and need for prototypes. Its ability to model driver behavior is currently limited and its use in experiments must be carefully considered in order to avoid dependence upon behaviors that cannot be implemented in time. Its effectiveness as a wingman to a human-operated, simulated vehicle is currently undergoing validation.

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## DEFINITIONS, ACRONYMS, ABBREVIATIONS

**CAT**: Crew integration and Automation Testbed, a mock crewstation used in TARDEC experiments

**ESS**: Embedded Simulation System, the software that mediates between the simulated environment and a vehicle in the experiments performed by TARDEC

**FCS**: Future Combat Systems, a set of next-generation vehicles under development by the U.S. Army

**HMI**: Human-Machine Interface

**IMPRINT:** IMproved Performance Research INtegration Tool, an application developed by Army Research Laboratory and used to create the VLHPM

**M&S**: Modeling and Simulation

**RDECOM**: U.S. Army Research, Development, and Engineering Command

**TARDEC**: Tank Automotive Research, Development, and Engineering Center

**VLHPM**: Vehicle Level Human Performance Model